

**An Ontological Framework for Contextualising
Information in Hypermedia Systems.**

by

Andrew James Bucknell

Thesis submitted for the degree of

Doctor of Philosophy

University of Technology, Sydney

2008

CERTIFICATE OF AUTHORSHIP/ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Student

A handwritten signature in blue ink is written over a horizontal line. The signature is stylized and appears to be 'A. Ruben'.

Dedication

This thesis, and the work that went in to it, is dedicated to Anthony & Margaret Bucknell – Mum & Dad. Your love, support and belief made it possible for me to persevere and succeed. For that, I am eternally grateful.

Acknowledgements

I would like to thank my supervisor, Prof. David Lowe for his advice, support, encouragement and especially his patience as I have undertaken the journey that is a PhD candidature. I would also like to thank the academic and support staff of CSE for creating an environment filled with enthusiasm for applying computer systems to real world problems.

Thank you to Lauren Scott for her assistance with proofreading this thesis. Thank you to Dr. Narelle Smith for her advice on statistical analysis and the staff at the Institute for Interactive Media and Learning for their assistance with Survey Manager.

Thank you to Andrew & Vanessa Watts and Sara & Colin Shorter for being the kind of friends who know me better than I know myself and love me for it.

Thank you to Ed Tobin, Steve Evans, Robyn & Sam Watts, Rodrigo & Marines del Busto, Wen Smallwood, and Alex Thompson for their friendship and for their generosity when I have most needed it.

Thank you to Phillip Kazanis and Sam Beskur who have given me invaluable advice and encouragement along the way, and who's friendship helped put tasks such as the one involved in writing a PhD thesis in perspective.

Finally, and most of all, I would like to thank my family for being all the things one could hope for in a family. My parents, for raising me to be who I am. My brother, Daniel and sisters, Karyn and Deborah, and their families, for being part of who I am. Your love and support has given me the strength to persevere and succeed.

Contents

1	Introduction	1
1.1	Background	2
1.2	Hypothesis	5
1.3	Research Method.....	5
1.3.1	Research Techniques	5
1.3.2	Research Questions	7
1.3.3	Approach and Thesis Structure.....	15
1.4	Contributions	18
1.5	Conclusion.....	19
2	Hypermedia and the World Wide Web	20
2.1	Introduction.....	21
2.2	Hypermedia	23
2.2.1	Hypermedia Concepts	23
2.2.2	Hypermedia Systems	25
2.2.3	Hypermedia Models	32
2.3	The World Wide Web.....	35
2.3.1	Web Technologies.....	35
2.3.2	Semantic Web.....	38
2.4	Information Seeking on the World Wide Web	39
2.4.1	Browsing	40
2.4.2	Searching	41

2.4.3	Information Seeking	42
2.4.4	Issues with Information-Seeking Behaviours on the World Wide Web.....	44
2.5	Conclusion.....	46
3	Information and Context	48
3.1	Introduction.....	49
3.2	Information Concepts.....	49
3.2.1	An Overview of Information Concepts	50
3.2.2	Shannon's Communication Theory	51
3.2.3	Information As A Property of Matter.....	51
3.2.4	Information As Structure	52
3.2.5	Information As Process	53
3.2.6	Information As Thing	54
3.2.7	Implications for this Research	55
3.3	A Concept of Context	55
3.3.1	The Varied Nature of Context.....	56
3.3.2	Information Concepts that Discuss Context.....	58
3.3.3	Context as <i>a priori</i> Knowledge.....	58
3.3.4	Context as situation.....	58
3.3.5	Context as information need	59
3.4	Context in Hypermedia Models	60
3.4.1	Metadata.....	60
3.4.2	Dublin Core	61

3.4.3	Warwick Framework	61
3.4.4	SHOE.....	62
3.4.5	RDF.....	62
3.4.6	Context in Dexter	63
3.4.7	Context in AHM	64
3.4.8	Context in Browsers.....	65
3.5	Conclusion.....	65
4	Ontology.....	67
4.1	Understanding Ontology	68
4.1.1	What is Ontology?	69
4.1.2	Goals of Ontology	74
4.2	Modelling a Domain with Ontology	75
4.2.1	Modelling Ontology on the World Wide Web	76
4.2.2	Creating an Ontology	78
4.3	Modelling Context with Ontology	82
4.3.1	Step 1 - Domain and Scope of the Ontology	82
4.3.2	Step 2- Consider re-using ontologies.	83
4.3.3	Step 3 - Enumerate important terms in the ontology	84
4.3.4	Step 4 – Define the classes and class hierarchy.....	87
4.3.5	Step 5 - Define the properties of classes – slots	91
4.3.6	Step 6 – Define the facets of slots	91
4.3.7	Step 7 – Create instances.....	92

4.3.8	Summary	92
4.4	Conclusion	92
5	Contextualisation	94
5.1	Introduction	95
5.2	User Interfaces	95
5.2.1	Side Bars	96
5.2.2	Toolbars	97
5.2.3	Browser Extensions	98
5.2.4	Desktop Search	98
5.3	Scenario Based Design	98
5.3.1	Identify Scenarios	99
5.3.2	Activity Design	102
5.3.3	Information Design	103
5.3.4	Interaction Design	105
5.3.5	Prototyping & Evaluation	106
5.4	Conclusion	106
6	Framework and Implementation	108
6.1	Framework	108
6.1.1	Application Frameworks	109
6.1.2	Designing the ICU Framework	112
6.1.3	Supporting the ICU Paradigm with Web Services	117
6.1.4	Creating the ICU Framework	118

6.1.5	Summary	121
6.2	Implementation.....	122
6.2.1	Client Implementation.....	123
6.2.2	Server Implementation	130
6.2.3	Summary	132
6.3	Conclusion.....	132
7	Evaluation	134
7.1	Evaluation	135
7.1.1	Evaluating Software.....	135
7.1.2	TAM.....	139
7.1.3	Method	141
7.2	Evaluation with TAM	143
7.2.1	Applying TAM.....	143
7.2.2	An Evaluation Methodology	144
7.2.3	Execution	148
7.2.4	Conclusion.....	151
7.3	Results.....	152
7.3.1	Data Collected	152
7.3.2	Analysis Tools	153
7.3.3	Analysis	154
7.3.4	Results.....	159
7.4	Conclusion.....	159

8	Conclusions and Further Work.....	161
8.1	Hypothesis Analysis	161
8.2	Research Outcomes	163
8.2.1	New Knowledge.....	163
8.2.2	Technical and Conceptual Knowledge	166
8.3	Further Research and Development	166
8.3.1	Research Questions	167
8.3.2	Applications	169
8.4	Conclusion.....	170
Appendix A.	Ontology of Context	171
Appendix B.	ISeeYou Screenshots	173
Appendix C.	IContextStoreService Interface.....	184
Appendix D.	Contextualisation Scenarios.....	196
D.1	Search Context Store	197
D.2	Search Result Set.....	199
D.3	Browse Context Store	201
D.4	Browse Result Set	203
D.5	View Hotlist.	205
D.6	View Dynamic Favourites.....	206
Appendix E.	Web Services Overview	207
E.1	Understanding Web Services.....	207
E.1.1	Using Web Services	208

E.1.2	Web 2.0	209
Appendix F.	Implementation Technical Notes	211
F.1	Client Technologies.....	211
F.1.1	Browser	211
F.1.2	COM Overview	212
F.1.3	Browser Helper Objects.....	212
F.1.4	Explorer Bands.....	213
F.1.5	Extensibility Technology	214
F.2	Server Technology.....	217
F.2.1	Message Service Component.....	218
F.2.2	Context Store Component	221
F.2.3	Service Technology.....	223
F.2.4	ISeeYou Functionality	225
F.3	Deployment	227
F.3.1	DLL's	228
F.3.2	Service	228
F.3.3	Data Location	229
F.3.4	Startup	230
F.3.5	Installer	230
Appendix G.	Survey Instrument.....	231
Bibliography		236

Table of Tables

Table 1-1 Information Seeking Behaviours on the World Wide Web (Choo, Detlor & Turnbull 2000)	4
Table 1-2 Thesis Structure	17
Table 2-1 Information acquisition interaction	42
Table 4-1 Important Domain Terms	86
Table 4-2 Domain Concepts	89
Table 5-1 Scenario-Based Design Phases	99
Table 5-2 Information Seeking Behaviours to support	100
Table 5-3 Information Seeking Scenarios	100
Table 5-4 Problem Scenarios for Behaviours	101
Table 5-5 Graphical Structures for Browsing	104
Table 6-1 ISeeYou Functions as Behaviours	130
Table 7-1 Evaluation Planning Phase	145
Table 7-2 Evaluation Execution Phase	145
Table 7-3 Scale items of the usefulness determinant	146
Table 7-4 Scale items of the ease of use determinant	147
Table 7-5 Likert scale items	148
Table 7-6 Survey Responses	153
Table 7-7 Analysing evaluation results	154

Table 7-8 Remove Incomplete Responses	155
Table 7-9 Remove Invalid Responses	156
Table 7-10 Complete and Valid Responses	157
Table 7-11 Principal Component Analysis.....	157
Table 7-12 Cronbach's Alpha for Constructs	158
Table 7-13 PU and PEOU for ISeeYou	159
Table D-1 Contextualisation Scenarios	196

Table of Figures

Figure 4-1 Representation of Concept Associations (UML 2.0)	90
Figure 6-1 ICU Architecture (UML 2.0)	113
Figure 6-2 Identify Component (UML 2.0)	115
Figure 6-3 Collect Component (UML 2.0)	115
Figure 6-4 Use Component (UML 2.0)	116
Figure 6-5 ICU Framework (UML 2.0)	122
Figure 7-1 Technology Acceptance Model (from Davis 1989)	140
Figure B-1 Google Search (1)	173
Figure B-2 Google Search (2)	174
Figure B-3 Google Search(3)	175
Figure B-4 Google Search (4)	176
Figure B-5 Most Recent Hosts	177
Figure B-6 Most Visited Hosts	178
Figure B-7 Most Recent Pages	179
Figure B-8 Most Visited Pages	180
Figure B-9 Page Information	181
Figure B-10 Local Search (1)	182
Figure B-11 Local Search (2)	183

Abstract

The Internet has become part of everyday modern life. A central component of the Internet is the World Wide Web. With hundreds of millions of users trying to find information they need amongst billions of pages, there is an urgent need for tools that help users find the information they need. A key element in assisting users find information is their context. Being able to model and store a user's context provides information about the user that can be used to augment their information-seeking behaviours. This work investigated the hypothesis that it is possible to create an ontology of context that can be used to create tools that users perceive to be useful and easy to use when performing information-seeking behaviours on the World Wide Web.

This hypothesis was investigated through three research stages. First, a concept of context was developed that applies to information-seeking behaviours on the World Wide Web. Next, this concept was modelled using an ontology, and a software framework was created based on this ontology. This framework was used to create tools that augment the information-seeking behaviours of users of the World Wide Web. Finally, an empirical evaluation of these tools was performed to determine if they were perceived to be useful and easy to use. The results of the evaluation indicate that the tools constructed were perceived to be useful and easy to use, providing evidence that supports the validity of the hypothesis. This outcome encourages further research and development into using an ontology of context to develop tools that help people using the World Wide Web to find the information that they need.

Extended Abstract

While context is an integral part of interacting with information, existing approaches to managing contextual information on the World Wide Web are application specific and do not support sharing contextual information. The consequence of this is that the contextual information in each application is stored in a way that is specific to that application, and the reuse of information between tools is not explicitly supported. This lack of explicit support for sharing contextual information between applications limits the effectiveness of tools that contextualise information. This thesis demonstrates that an open model of context can be used across applications to contextualise information, and that users find tools based on this approach to contextualisation to be useful.

This hypothesis for this research states that *it is possible to create an ontology of context that can be used to create tools that users perceive to be useful and easy to use when performing information-seeking behaviours on the World Wide Web*. This hypothesis is investigated through three research stages: development of a concept of context that is application neutral; demonstration that this concept of context can be used to contextualise information on the World Wide Web; an empirical evaluation that shows that it is possible to create useful tools using this model.

The concept of context was developed by undertaking a critical analysis of the literature and using this to explicitly identify the role of the user's context in information-seeking behaviours on the World Wide Web. This concept is developed over two phases of investigation. The first phase reviews hypermedia models and systems, including the World Wide Web, to identify the goals of hypermedia and the approaches to information management that are used to achieve these goals. This review identifies the interaction of a user with web resources in producing information as being fundamental to

hypermedia. The next phase of the critical analysis builds on this understanding of hypermedia to develop a concept of context that explicitly includes data about the user as a construct a user's interaction with web resources.

Demonstrating the use of the concept of context to contextualise information on the World Wide Web involved two phases of research. The research in the first phase shows how the concepts expressed in the concept of context can be represented using the Web Ontology Language. The second phase develops a software framework based on the ontology of context that can be used to identify, collect and use contextual information. This framework, the ICU framework, encompasses existing approaches to contextualisation while also providing an open architecture based on web services that can be used to make contextual information available to applications that contextualise information. The utility of this framework is demonstrated by constructing a tool that implements existing contextualisation interfaces in a single tool, using the one collection of contextual information. This tool is called ISeeYou.

The empirical evaluation used the Technology Acceptance Model (TAM) to investigate the usefulness and ease-of-use of ISeeYou for users engaging in their regular information-seeking behaviours on the World Wide Web. TAM has been shown to be effective in evaluating the usefulness and ease-of use of new technologies, and has been successfully applied to evaluating web-based technologies. The results of this evaluation indicate that tools based on the framework and the ontology are useful and easy-to-use when performing information-seeking behaviours on the World Wide Web. This outcome encourages the further development of tools that use the ICU framework and further development of ontologies that represent the context of users of the World Wide Web.

This research investigated an approach to managing contextual information that allows reuse of contextual information by using an open architecture and offers a richer set of contextual information by structuring the information using an ontology. By creating an open shareable model of context, the constraints on using contextual information across different contextualisation tools is removed and richer tools for contextualising information on the World Wide Web can be created. This research is predicated on the belief that contextualisation of information on the World Wide Web is an essential tool for helping users manage information, and the development of tools that perform contextualisation is an ongoing challenge for researchers and developers. The ontology and the framework developed in this work aim to help meet this challenge. The research carried out in this work demonstrates that it is possible to create an ontology of context that can be used to create tools that users perceive to be useful and easy to use when performing information-seeking behaviours on the World Wide Web. This result encourages further research in to an ontology-based model of context that explicitly is focussed on the user.